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Research Article

The Analysis of the Benefit of the Dual Channel Retailing with Green Innovation in the Supply Chain Management

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ABSTRACT

A dual-channel retailing is crucial in a supply chain management. The integration of dual channel and the green innovation is investigated in this study. The research explores how the integration of online and offline retail channels can be leveraged to implement sustainable practices across the supply chain, while simultaneously enhancing customer engagement and brand perception. By examining the impact of greening initiatives on operational efficiency, logistical flows, and consumer behavior, this paper identifies key strategies for optimizing dual-channel operations to achieve both economic and environmental sustainability. Through a comprehensive analysis of industry best practices and theoretical frameworks, this study provides insights into the critical success factors for integrating sustainable supply strategies within a dual-channel retail model, ultimately contributing to a more environmentally conscious and economically viable retail ecosystem. This retailing framework is determined through game policy. The numerical results point out that without an offline channel in decentralized policy and centralized policy increase the total profit by 59.2% and 58.62% respectively.

Keywords: Dual channel retailing; Greening innovation; Supply chain management; Transportation

INTRODUCTION

Retail space evolution has seen tremendous growth in dual-channel (DC) programs through online and offline channel where companies merge physical stores and online stores with virtual platforms to address the various needs of consumers (Sun & Liu, 2023). With such changing scenarios, the interface between supply chain (SC) and retailing takes center stage as the primary agenda item, particularly when coupled with the need for green innovation. Business firms are being forced to go green as awareness regarding environmental issues in people rises (Mridha et al., 2023). Businesses should strike a balance between supply chain management (SCM) and using smart retail measures that go together in an effort to develop green innovation in two-channel systems (Pai & Hungund, 2025). Leaping past the challenges of DC retailing (Hu et al., 2024), integrating innovation with greening presents a new opportunity and challenge (Zhang et al. 2021). With consumers increasingly embracing green products and behaviors, businesses need to place their SC initiatives strategically to not only fulfill these needs but also drive sustainable growth. This involves reconsidering logistical operations, from manufacturing and sourcing to distribution and reverse logistics, to reduce the environmental footprint. On the other hand, retailing strategies must communicate the value proposition of green activities and products, earning consumers' trust and loyalty (Chkanikova & Mont, 2015; Zhong & Um, 2025). Research into the interaction between these fields is essential to determine how companies can utilize DC structures (Nematollahi et al., 2024) to promote and disseminate greening innovation and help create a more sustainable and responsible retail environment (Li et al. 2024).

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Fig. 1. Diagram illustrating the proposed model

OBJECTIVES

The impact of DC in an SCM with green innovation is shown in this study. To mitigate adverse environmental consequences, manufacturers are engaged in the development of green products that drive innovation toward more efficient and renewable technologies, thereby promoting a sustainable future for forthcoming generations. To enhance the revenue of both players, the manufacturer and retailer accept transportation costs separately due to their transportation costs.

LITERATURE REVIEW

The research on DC retailing, in which companies sell goods through both physical and virtual channels, examines different aspects of this retailing strategy. Dutta et al (2025) worked on dynamic pricing in DC retailing. This study highlighted the effect of DC retailing, where customers can purchase products from DCs. Mahapatra et al. (2025) examined the effect of demand patterns for DC retailing in SCM. Qiu et al. (2024) explained the effect of customer behavior in an DC SCM. This study introduces a virtual showrooming behavior between the retailer, the manufacturer, and the customer. Joshi et al (2024) developed an approach for generation and gender differences in DC retailing. This study investigated customer behavior by depending socio socio-demographic variables.

Davoudi et al. (2023) introduced a pricing strategy (Yang et al., 2024) with green innovation in SCM, which explained the effect of bargaining on pricing for green products. Guo et al. (2025) presented the effect of green innovation on the green financial system. This study measured the importance of green bonds and green credit in the green financial system. Nichifor et al. (2025) discussed a food consumption method in the green SC. This study provided a thorough classification of the factors that drive consumers to choose sustainable food options. Sarkar et al. (2025b) investigated a proper way to reduce the waste of water. Barati (2025) developed a dynamic approach in SCM, where the cost of the SC was minimized by using blockchain technology. Wang et al (2024) worked to reduce carbon emission from transportation. This study used AI technology to reduce carbon emissions. Wang et al. (2025) worked on transportation by using social media information. This study investigated approximately 30000 passengers' information at an airport.

NOTATION AND ASSUMPTION

Problem definition: An DC green SCM is developed, where the total demand of the study is a function of the greening level of DCs and the selling price of online and offline channels. To make the model more perfect, the decentralized and centralized decision models are developed individually. Two transportation costs of manufacturer and retailer are utilized.

All notations of this study are expressed in **Table 1**

Table 1: Notation of this study

Decision variable	Description
v_j, μ_j, σ_j	Selling price, wholesale price and investment for green innovation, respectively
Parameter	Description
Z_j, Y_j	Customer sensitivity of the selling price and green innovation, respectively. $Z_j > Y_j + 1$
χ_j, ψ_j, B_j, and A_j	Variable and constant transportation cost of manufacturer and the retailer, respectively.

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N_j, and E_j ϖ_j, and U_j	Manufacturing cost and investment parameter of green groduct, respectively. Retailer's margin and the total population of potential customers, respectively.
Index	Description
j	1 , 2. (1 for online channel and 2 for offline channel)

The assumptions about those problems are as follows

1. An DC green SCM model is investigated, where the manufacturer produces environmentally friendly products and sends products through both channels, whereas the retailer opens DC retailing or the customer.
2. Demand depends on the degree of green innovation and the price of selling, and is expressed by the formula $\sum_{j=1}^{2} U_j\, v_j^{Z_j}\, \sigma_j^{Y_j}$, where the condition $Z_j > Y_j + 1$ is valid. The retailer's marginal profit per unit is calculated as $\varpi_j = v_j - \mu_j$. The manufacturer allocates an investment of $E_j\sigma_j^2$ toward green innovation.
3. The manufacturer and retailer allocate funds toward both variable and fixed transportation expenses, as well as various maintenance-related activities. These include costs for durable packaging, pre-shipment and post-delivery inspections, labor, employee training, documentation, and monitoring tools.

MODEL AND METHOD

The profit equation of the retailer (Π_R), manufacturer (Π_M), and SCM (Π_{SC}) is expressed respectively as

$$\Pi_R = \sum_{j=1}^{2}(v_j - \mu_j - \psi_j)U_j\, v_j^{Z_j}\, \sigma_j^{Y_j} - A_j = \sum_{j=1}^{2}(\varpi_j - \psi_j)U_j\,(\varpi_j + \mu_j)^{Z_j}\, \sigma_j^{Y_j} - A_j \tag{1}$$

$$\Pi_M = \sum_{j=1}^{2}(\mu_j - N_j - \chi_j)U_j\, v_j^{Z_j}\, \sigma_j^{Y_j} - E_j\sigma_j^2 - B_j = \sum_{j=1}^{2}(\mu_j - N_j - \chi_j)\, U_j\,(\varpi_j + \mu_j)^{Z_j}\, \sigma_j^{Y_j} - E_j\sigma_j^2 - B_j \tag{2}$$

$$\Pi_{SC} = \sum_{j=1}^{2}(v_j - N_j - \psi_j - \chi_j)U_j\, v_j^{Z_j}\, \sigma_j^{Y_j} - E_j\sigma_j^2 - A_j - B_j \tag{3}$$

Decentralized model

In this problem, a Stackelberg game policy with manufacturer leader and retailer follower is considered.

Equation (4) is obtained by differentiating equation (1) with respect to ϖ_j and equal to zero

$$\varpi_j(\mu_j) = (\mu_j + Z_j\,\psi_j)/(Z_j - 1) \tag{4}$$

Solution of the model

putting the value of $\varpi_j(\mu_j)$ in Eq. (2) and differentiating concerning μ_j and σ_j the Eq. (5) and (6) is obtained

$$\mu_j^* = \frac{Z_j N_j + \psi_j + \chi_j Z_j}{Z_j - 1} \tag{5}$$

$$\sigma_j^* = e^{\frac{\ln(2) + \ln\frac{E_j(Z_j-1)}{Y_j U_j(N_j+\psi_j+\chi_j)} + Z_j ln\frac{Z_j^2(N_j+\psi_j+\chi_j)}{(Z_j-1)^2}}{Y_j - 2}} \tag{6}$$

By using equations (4), (5) and $\varpi_j = v_j - \mu_j$, equation (7) is obtained

$$\varpi_j^* = \frac{Z_j(N_j - \psi_j + \chi_j) + \psi_j(1 + Z_j^2)}{(Z_j-1)^2}\quad,\quad v_j^* = \frac{Z_j^2(N_j + \psi_j + \chi_j)}{(Z_j-1)^2} \tag{7}$$

Therefore, the optimal profit equation of the retailer (Π_R^*), manufacturer (Π_M^*), and SCM (Π_{SC}^*) is as follows

$$\Pi_R^* = \sum_{j=1}^{2}\lambda_j(v_j^* - \mu_j^* - \psi_j)U_j\,(v_j^*)^{Z_j}\,(\sigma_j^*)^{Y_j} - \lambda_j A_j \tag{8}$$

$$\Pi_M^* = \sum_{j=1}^{2}(\mu_j^* - N_j - \chi_j)U_j\,(v_j^*)^{Z_j}(\sigma_j^*)^{Y_j} - E_j(\sigma_j^*)^2 - (1-\lambda_j)\,(v_j^* - \mu_j - \psi_j)U_j\,(v_j^*)^{Z_j}\,(\sigma_j^*)^{Y_j} - (1-\lambda_j)A_j - B_j \tag{9}$$

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$$\Pi_{SC}^{*} = \sum_{j=1}^{2}(\nu_j^{*} - N_j - \psi_j - \chi_j)U_j\left(\nu_j^{*}\right)^{Z_j}\left(\sigma_j^{*}\right)^{Y_j} - E_j\left(\sigma_j^{*}\right)^{2} - A_j - B_j \quad (10)$$

Centralized model

In this study, the retailer and the manufacturer make decisions together for maximizing the profit of the GSCM.

Solution of the model

The Equation (11) is obtained by differenciating with respect to σ_j and ν_j

$$\sigma_j^{*} = e^{\frac{\ln(2)+\ln\frac{E_j(Z_j-1)}{Y_jU_j(N_j+\psi_j+\chi_j)}+Z_j\ln\frac{Z_j(N_j+\psi_j+\chi_j)}{(Z_j-1)}}{Y_j-2}}, \qquad \nu_j^{*} = \frac{Z_j(N_j+\psi_j+\chi_j)}{(Z_j-1)} \quad (11)$$

Therefore, the optimal profit equation in the centralized policy is as follows

$$\Pi_{SC}^{*} = \sum_{j=1}^{2}(\nu_j^{*} - N_j - \psi_j - \chi_j)U_j\left(\nu_j^{*}\right)^{Z_j}\left(\sigma_j^{*}\right)^{Y_j} - E_j\left(\sigma_j^{*}\right)^{2} - A_j - B_j \quad (12)$$

RESULTS

For finding the optimal result, MATLAB R2023b is used in this model. To find the optimal result, the following input prameters are utilized (Davoudi et al., (2023)). E_1=35, $U_1 = 9600$, b_1= 9.09, N_1 =1.1, $Y_1 = 0.5$, $Z_1 = 2.5$, $\chi_1 = 3.5$, $A_1 = 5.3$, $\psi_1 = 0.8$, $B_1 = 0.8$, E_2=34, $U_2 = 9500$, b_2= 9.08, N_2 =1, $Y_2 = 0.49$, $Z_2 = 2.4$, $\chi_2 = 3.4$, $A_2 = 4.3$, $\psi_2 = 0.9$, $B_2 = 2.4$. The optimal result and decision variables of the problem in decentralized and centralized policies are Π_R^{*}= 94.43, Π_M^{*} = 41.73, Π_{SC}^{*}= 136.16, Π_{SC}^{*}= 241.24, σ_1^{*}= 0.43, σ_1^{*}= 1.01, σ_2^{*}= 0.45, σ_2^{*}= 1.19, ν_1^{*}= 15, ν_1^{*}= 9, ν_2^{*}= 15.58, ν_2^{*}= 9.08, μ_1^{*} = 8.2 and μ_2^{*} = 8.18. Fig 2 and Fig 3 are represented the concavity of the profit of decentralized policy (DP) and centralized policy (CP) respectively.

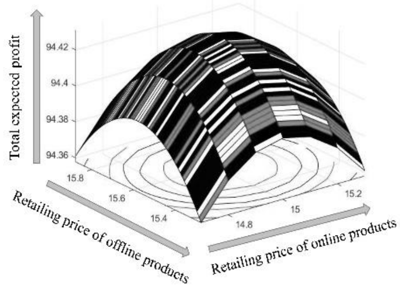

Fig 2 Figure of concavity of DP profit function

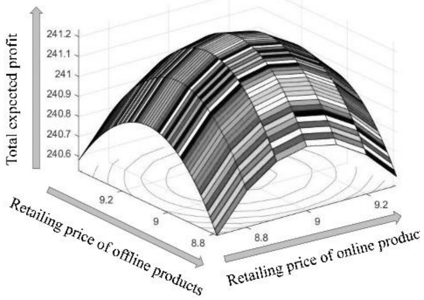

Fig 3 Figure of concavity of CP model's profit function

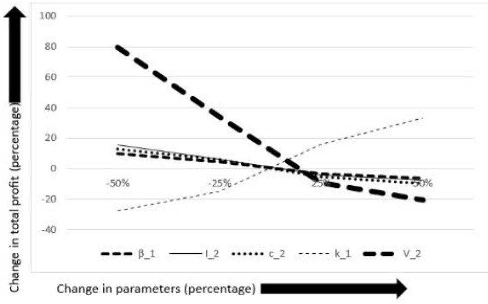

Fig 4 Figure of sensitive analysis

Some special cases

Without offline channel is considered in this case. The optimal result and decision variables in decentralized policy are Π_R^{*}= 38.11, Π_M^{*} = 17.43, Π_{SC}^{*}= 55.55, σ_1^{*}= 0.43, ν_1^{*}= 15, and μ_1^{*} = 8.2, in the centralized policy are Π_{SC}^{*} = 99.83, σ_1^{*}= 0.58, and ν_1^{*} = 12.57. Comparatively, without an offline channel, there will be profit declines of 55.66% for the retailer, 58.23% for the manufacturer, and 59.2% and 58.62% for the overall SCM for the respective policy. Hence, integration of an online channel is very beneficial to all the parties involved.

Sensitive analysis

Six key parameters α2, β2, c2, k1, I2, and V1 are analyzed through sensitivity analysis. The impact on the SCM's profit is evaluated by varying each parameter by ±50% and ±25%, as presented in Table 4. The results indicate that α2 is extremely sensitive, while k1 and V1 are highly sensitive parameters. The remaining parameters also show sensitivity to some extent (Figure 4).

Table 2 Sensitivity analysis of principal parameters

	Parameter(P)	Changes (in%)	Π_{SC}^{*}	P	Changes (in%)	Π_{SC}^{*}	P	Changes (in%)	Π_{SC}^{*}
Centralize policy	Y_1	-50%	9.77	U_1	-50%	-27.88	N_2	-50%	12.93
		-25%	4.29		-25%	-14.72		-25%	6.01
		+25%	-3.45		+25%	16.02		+25%	-5.25
		+50%	-6.29		+50%	33.15		+50%	-9.87
Decentralized policy	Z_2	-50%	3619.473	E_2	-50%	15.48	χ_1	-50%	79.44
		-25%	327.73		-25%	6.01		-25%	33.66
		+25%	-50.12		+25%	-4.29		+25%	-9.22
		+50%	-59.15		+50%	-7.57		+50%	-20.36

MANAGERIAL INSIGHTS

1. In an DC SCM, reducing selling prices leads to higher profits because demand in both channels rises as prices fall. As a result, it's important to carefully determine selling prices in each channel to boost demand and optimize overall SCM profit.
2. Product demand is affected by the adoption of green innovation in both online and offline channels. Research shows that increased efforts in green innovation across both channels can enhance SC profitability. Therefore, managers should prioritize strengthening green innovation strategies across all sales channels.

CONCLUSION AND FUTURE EXTENSION

An SCm model with DC retailing was considered. This was considering that the model allowed firms to react to fluctuations in customers' preferences, increases green product availability, and encourages more eco-performance. Empirical evidence indicated that DC systems can enable increased product greenness and profitability, especially when supported by coordination mechanisms such as cost-sharing contracts. Consumer trust in environmental labels, such as third-party certified labels, also greatly influenced purchasing behavior. Although issues such as channel conflict and price disparity were there, these could be addressed through strategic coordination and openness in practice. Overall, DC retailing was an effective and promising vehicle to enable the adoption of green products in a competitive, growing, and environmentally conscious market scenario. Without an offline channel, the profit was decline by 59.2% and 58.62% for the overall SCM for the DP and CP, respectively. Multi-cycle smart production system (Sarkar et al. 2025a, Guchhait & Sarkar 2025), promotional effort (Kumar et al. 2025), cybersecurity (Erdem et al. 2025), artificial intelligence (Volkmar et al., 2022) can be added in this paper for further extension.

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